The Correlation of the Defibrillation Threshold and the Upper Limit of Vulnerability using Catheter-Patch Defibrillating Electrodes

Katherine M Kavanagh MD, Jenny H Harrison BS, Ellen G Dixon MS, William M Smith PhD, J Marcus Wharton MD, Raymond E Ideker MD, PhD, FACC, Duke Univ Med Ctr, Durham, NC

The upper limit of vulnerability (ULV) hypothesis states that shocks slightly weaker than those required to defibrillate stop all activation fronts but reinitiate ventricular fibrillation (VF) by stimulating myocardium during the vulnerable period. The ULV has been shown to be closely correlated with a high defibrillation probability (DFP) of success using epicardial electrodes. This study investigates the relationship of the DFP to the ULV using catheter patch electrodes to determine if the ULV and hence the DFP can be estimated at a single well defined time during the vulnerable period, i.e., the peak of the T-wave in ECG lead II. This could be clinically significant for reducing the number of VF inductions required to insure that implantable defibrillators are set at optimal energy levels (>80% DFP). In 6 anesthetized dogs, DFP curves were constructed from a mean of 9 $\pm$ 2 defibrillation threshold determinations using single capacitor biphasic waveforms with a 6-6 msec first-second phase duration delivered to a 6.2 cm transvenous catheter electrode with a distal pacing tip inserted into the RV apex and a 113 cm^2 cutaneous patch on the left lateral thorax. ULV was determined by scanning across the duration of the T wave in 10 ms increments with S2's delivered after a drive train of 10 S1's at a pacing length of 300 msec. If VF was induced, scanning was stopped and the voltage increased by 20%. Scanning was then reinitiated until VF was again induced or diastole was scanned without VF induction i.e., the maximum ULV. The ULV protocol was performed 3 times. The mean 80% DFP leading edge voltage (V1l) was 334 $\pm$ 39. The mean ULV V1l at the peak of the ECG T-wave was 330 $\pm$ 31. These values were significantly (p=0.03) correlated with a correlation coefficient of 0.85. This suggests that shock energy could be decrementally introduced at the peak of the T-wave until VF was induced and that the energy level one increment above that introducing VF would be a good estimate of the ULV and would predict the shock strength having an 80% DFP. This method would allow determination of the 80% DFP with only a single induction of VF.

VERAPAMIL INCREASES THE INTERNAL DEFIBRILLATION ENERGY REQUIREMENTS IN ANESTHETIZED DOGS

Rainer Schräder, M.D., Michael Brooks, B.S., Debra S. Echt, M.D., F.A.C.C., J. W. Goethe Universität, Frankfurt, FRG and Vanderbilt University, Nashville, TN

Antiarrhythmic drugs and calcium antagonists are often required in pts with automatic implantable cardioverter-defibrillators (AICD). To evaluate the effects of verapamil on internal defibrillation (DF) energy requirements, 20 dogs were investigated. Ventricular fibrillation (VF) was induced with AC current and DF energies were applied across 2 epicardial patch electrodes (Cardiac Pacemakers). To characterize the relationship between the energy and the % of successful DF attempts, 4 energy levels, ranging between failure and success, were tested on 5 occasions each. The energies required to achieve 50 and 90% success in DF (E50, E90) were calculated. Other measurements included surface ECG and His bundle intervals, VF cycle length, sinus node recovery time, Wenckebach cycle length, CO, AO and PA pressures, post-DF AO pressure changes, and verapamil plasma levels. In 10 control animals, this protocol was performed 3 times in sequence (phases A, B, and C). In 10 other dogs, after baseline testing (phase A), the protocol was repeated with 2 verapamil infusions: for phase B, 0.125 mg/kg load and 2.5 μg/kg/min maintenance; and for phase C, 0.25 mg/kg load and 5 μg/kg/min maintenance.

Control	E50(J)	E90(J)	Verapamil	E50(J)	E90(J)	
Phase A	8$\pm$4	10$\pm$4	Phase A	8$\pm$4	11$\pm$5	
Phase B	8$\pm$4	11$\pm$6	Phase B	12$\pm$6	16$\pm$9*	*p<.05
Phase C	8$\pm$4	11$\pm$5	Phase C	17$\pm$10**	20$\pm$11**	**p<.01

In controls, E50 and E90 remained unchanged, but significantly increased after verapamil infusion. The % change in VF cycle length was related to the % change in E50 and E90 by non-linear regression (p<0.001, r>.80). This experimental data may suggest that verapamil should be used in patients with the AICD only after individual testing.

SIGNIFICANCE OF SEPTAL RECRUITMENT FOR DEFIBRILLATION.

Igor Singer, M.D., Claudio Maldonado, M.S., Fred Vance, M.E., Al Dawson, Ph.D., Takeshi Noda, M.D., Joel Kupersmith, M.D., F.A.C.C.. University of Louisville, KY.

To explore the hypothesis that septal recruitment is important in lowering the defibrillation thresholds, two 6.5 F electrodes (NuMed, Hopkinton, N.Y.), with 5 cm platinum-iridium coils were positioned at the right ventricular apex (RVA) and the right ventricular outflow (RVO) in 8 dogs. Cutaneous R2 pad (P) was placed at the point of the maximal cardiac impulse. Biphasic pulses were delivered, first pulse (6 ms) positive, the second negative (2 ms), separated by 0.5 msec. The leading edge of the second pulse was equal to the trailing edge of the first. A 67% probability of success was defined for RVA^-/P^+ (1) by a stepwise reduction in voltages. At a constant voltage output RVA^-/P^+ was then compared to $RVA\text{-}RVO^-/P^+$ (2) and RVO^-/P^+ (3) 10 trials each, in a random fashion. Results:

	RVA^-/P^+	$RVA\text{-}RVO^-/P^+$	RVO^-/P^+	p
%Success	67	81	60	<0.03
Energy*	9.7$\pm$3.3	10.5$\pm$3.8	10$\pm$3.5	<0.0001
Current*	8.7$\pm$1.9	9.9$\pm$2.3	9.0$\pm$2.0	<0.0001
Imped.*	75$\pm$12	66$\pm$12	72$\pm$9.6	<0.0001

*Energy (joules); Current (amps); Imped. (ohms) Mean$\pm$SE

Two electrodes positioned at RVA, but not in contact, were then connected to form a common cathode $RVA\text{-}RVA^-/P^+$ and compared to RVA^-/P^+, 10 trials each randomly in 5 dogs. There was no significant difference in % success, energy, current or impedance (p=0.05). Conclusions: 1) At constant voltage settings with biphasic pulses, % success, current and energy are greatest and impedance least for configuration (2). 2) Differences are most likely due to spatial orientation of electrodes resulting in increased recruitment of the septal mass and unrelated to surface area of electrodes.

Tuesday, March 20, 1990
10:30AM–12:00NOON, Room 14
Transesophageal and Intraoperative Echography II

TRANSESOPHAGEAL COLOR DOPPLER ECHOCARDIOGRAPHIC ASSESSMENT OF SHUNT FLOW AT ATRIAL LEVEL

Rajendra H. Mehta, M.D., Frederick Helmcke, M.D., Sudhir D. Bhimani, M.D., John W. Cooper, Raj S. Ballal, M.D., Navin C. Nanda, M.D, F.A.C.C., University of Alabama at Birmingham, Alabama

Transesophageal color Doppler echocardiographic examination (TEE) and cardiac catheterization (CC) were performed in 13 adult Pts (mean age 42 years) with a shunt at the atrial level. Five had ostium secundum atrial septal defect (ASD), 4 acquired ASD following transeptal puncture, 2 ostium primum, 1 sinus venosus type and 1 single anomalous pulmonary venous connection (APVC). Ten shunts were detected by CC and 13 by TEE. The 3 shunts not detected by CC were small acquired ASDs. Nine Pts had a shunt flow ratio by CC $\geq$1.5:1. Shunt flow (QP-QS) at TEE was derived by multiplying ASD or APVC area, mean velocity, flow duration and heart rate and was compared with QP-QS at CC. Mean velocity was calculated from color guided pulsed Doppler spectral trace or from a previously validated method analyzing color pixel intensity from color M-mode of ASD flow. Shunt direction was determined with color guided pulsed or M-mode Doppler. QP-QS by TEE (ranging from 0.18 to 15.94 l/min, mean 5.3) and by CC (ranging from 0 to 17.64 l/min, mean 6.01) correlated well (r=0.90, p<0.05). One Pt with severe pulmonary hypertension had right to left shunt confirmed by CC (0.5 l/min by CC, 0.6 l/min by TEE). TEE also detected trivial right to left shunting with atrial contraction in the 9 Pts with shunt ratio $\geq$1.5:1 and during isovolumic relaxation in 3 of these. TEE is useful for assessing shunt flow volume, detecting site of shunt and shunt direction.